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An interview with Igor Troitski

Laser-induced damage creates interior images

What is a laser-induced-damage image?

A laser-induced-damage image (LIDI) is a multitude of etch points inside any optically transparent material created by a pulsed laser beam that is periodically focused at preset points.

The first "intellectual" composition of these etch points was created in U.S. and Russian labs shortly after laser-induced-damage research started. These were 2D images of simple ornaments and words. In the U.S., similar images inside plexiglas objects were made by Prof. M.J. Soileau and his colleagues in 1987 and 1988. In Russia, the images were produced in crystal glasses. The method developed rapidly after Perestroika, when many Russian laser scientist and engineers who had been involved in military research lost their jobs and government funding.

Can you describe the latest version of the LIDI production system

The system is comprised of two subsystems. The first is the Computer Graphic System (CGS), which processes the image and transforms it into a great number of pixels, determining those points of the design or model in which the breakdowns are required to create the image in the optically transparent material. The second is the laser system, which uses the information from the computer graphic system to produce the image in the material by focusing a pulsed laser beam at preset points.

What is the number of points needed to produce a high-quality image?

Our experience proves that usually a good 50 X 50 X 50-mm 3D image requires about 50,000 to 60,000 etch points. About 100,000 are needed to reproduce a high-quality 2D 50 X 60-mm portrait.

How do you avoid crashes inside the glass or other material when using such a large number of damage points?

There is the value *d* of the minimum distance between adjacent etch points in optically transparent material for a selected energy of laser radiation. If the distance between two adjacent etch points in plane XY, perpendicular to a laser beam, is smaller than *d*, a crash (internal split) may occur. The value *d* of the *minimum* distance depends on the laser radiation energy used to produce these points and on the material properties.

Also, there is the value *L* of the minimum distance between adjacent etch points along the beam for a selected energy of laser radiation. If the distance between two adjacent etch points that are placed one after another along the laser beam is smaller than *L*, a crash may occur.

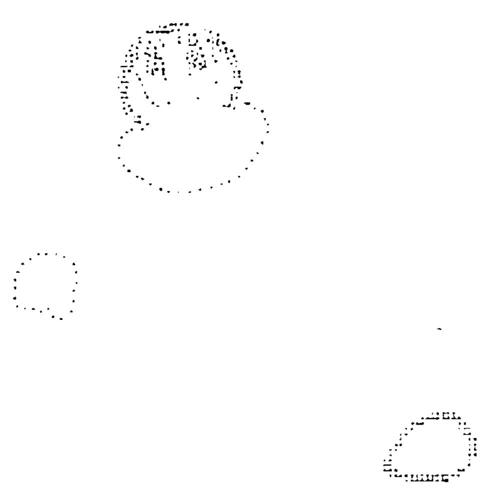
Often, a multitude of points is generated by cutting the entire displayed image by

parallel planes perpendicular to the direction of the laser beam so the points are placed only in these planes. In this case, the distance between adjacent planes is equal to L and the distance between adjacent etch points is equal to d.

Figures 1 and 2 show a cross-section of a 3D image of Mickey Mouse, and Figure 3 illustrates the 237 points in cross-section 37. Figure 4 is a 3D image of Mickey Mouse produced in an optically polished, high-index lead oxide (PbO) glass, known also as lead crystal. There are 157 parallel planes cutting the entire displayed image and the total number of etch points of the image is 19,308.

Figure 1. Two projections of a 3D image of Mickey Mouse on (a) plane XY, and (b) plane YZ. 19, 20, 37, 38, 50, 51, 61, 62, 99, and 100 are several of the parallel planes that divide the entire image. The distance between them is equal to L.

Why is the number of points for 2D portraits higher than for 3D images?



The value of d, the minimum distance between adjacent etch points in the material, is usually a value that enables one to see adjacent etch points as individual points. As a result, any image reproduced in a transparent material has a rough point structure visible to the naked eye (Figure 3). Obviously, this kind of point structure may be good enough for a 3D image, but it may not be acceptable for a portrait.

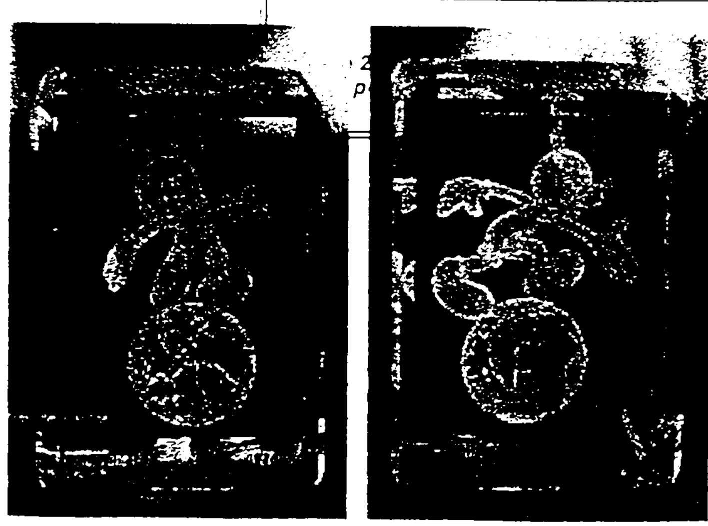


Figure 3. Two images of 3D Mickey Mouse produced inside a lead

crystal (front and side view).

How do you avoid this unacceptable effect if you are limited by the value of d?

A portrait can be produced using several layers. Every plane (layer) is parallel with respect to the portrait plane and perpendicular to the laser beam. The distance between adjacent parallel planes is set equal to the minimum distance L, so the material does not break. The etch points in every layer are arranged so that the distance between adjacent points is equal to the minimum distance d, but projections of all points of all layers on the portrait plane densely fill in the entire region of the image. So several layers are produced instead of one layer, but an observer perceives this "sandwich" as a one-layer completed portrait without a sharp point structure.

Figure 4. *Image of 3D Mickey Mouse (17, 301 etch points) and 2D image of Walt Disney portrait (32, 503 etch points).*

Transforming all the image pixels into etch points in the material has a profound effect on the quality of a reproduced portrait. But how do you transfer the brightness of the pixels into the material?

There are several methods. One is based on the following physical phenomenon: the more etch dimension the greater the brightness. For example, different etch point dimensions can be obtained by changing the laser energy. Etch point dimensions increase with an increase in laser radiation energy. Another method is that the greater the density of points in a given area, the greater the summary brightness of the area.

Have you patented the above methods of computer graphic systems?

Yes. One patent application is approved and three more are pending.

What do you think will be the likely future developments of this exciting technology?

All basic investigations are now directed toward creating color images. This is a difficult next step, but we have high hopes.

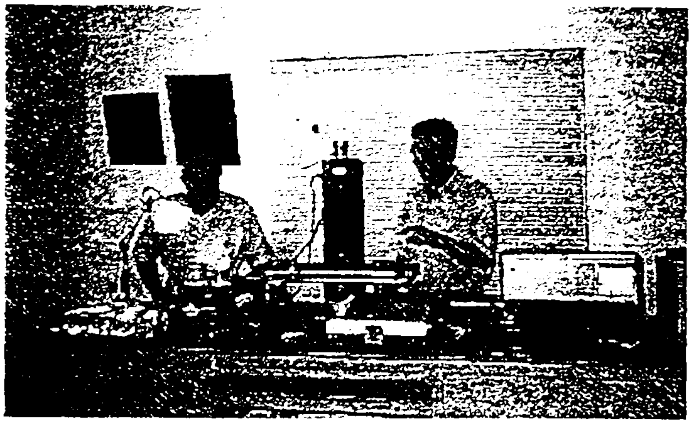


Figure 5. Edmund Akopov (left) and Igor Troitski with the laser-damage-image sys

Igor N. Troitski *was born in 1941. He graduated from the Moscow Physical and Technical Institute in 1965 and, in 1969 and 1978, received his Candidate of Technical Sciences (PhD) and Doctorate of Technical Sciences, respectively. For more than ten years, he held a full professorship at the Moscow Physical and Technical Institute. He is the author of more than 100 scientific works, including four books. He holds 63 Russian patents and one U.S. patent, and he has three U.S. patents pending. He has worked in the U.S. since 1994 and now has his own physical lab in Nevada, where he researches new methods of creating images inside transparent materials using lasers. He was interviewed by* ***Edmund Akopov****, Executive Director of the SPIE Russia Chapter and Development Director of SPIE Russia FSU.*

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